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"Response of Stream Biotic Riparian and Physical Conditions to Fire And Watershed Management"
IDAHO STATE UNIVERSITY
FS Contact: Mr. Kerry Overton
CoOp Contact: Dr. G. Wayne Minshall

Stream Ecology Research for 1994:

1) Post-Fire Years 10 and 15 for the 1979 Mortar Creek Fire

2) Yankee Fork Creek Mining Impacts

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Prepared By

Christopher T. Robinson and G. Wayne Minshall
Stream Ecology Center
Department of Biological Sciences
Idaho State University
Pocatello, Idaho 83209

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Summary

The present report addresses results from two separate projects. One study compared streams from burned and unburned catchments of the 1979 Mortar Creek fire in post-fire years 10 and 15. The results indicated little physical difference between 1989 and 1994 in streams influenced by this fire, although mainstem L. Loon Creek experienced major channel change. This channel change may have been a result of a new bridge installed just downstream of the permanent transect or potentially the occurrence of headcutting resulting from the fire on initial (1-5 years post-fire) channel cutting and rearrangement. Further, the macroinvertebrate data suggest that smaller streams were still experiencing the influence of the fire, whereas larger burn streams had similar assemblages as respective reference sites.

The other study examined for changes in Jordan Creek as a result of the recent increased mining activities in the basin. Jordan Creek habitat and macroinvertebrates were compared with conditions found in the Upper Yankee Fork and West Fork Yankee Fork. An additional site was located downstream of the Jordan Creek and Yankee Fork confluence. The data suggest subtle differences in habitat conditions and biotic assemblages between Jordan Creek and Upper Yankee Fork. For example, water temperatures and periphyton AFDM were higher in Jordan Creek than Upper Yankee Fork probably a result of the reduced riparian vegetation along Jordan Creek. Further, miners (chironomids) and filterers were more common in Jordan Creek and scrapers were more abundant in Upper Yankee Fork. However, 8 of the most 16 common taxa were found in both sites suggesting good potential recovery once habitat conditions are improved in Jordan Creek. Of note, the bacterium *Sphaerotilus* was quite prevalent in WF Yankee Fork suggesting organic pollution from anthropogenic sources. Also, chironomids comprised 49% of the assemblage at this site.

Introduction

Mortar Creek Fire (1979)

Wildfires are an integral component of terrestrial and aquatic environs in the Intermountain West. However, the amount of research on the effects of fire on these environments is amazingly sparse, with most literature emphasizing the changes that occur on the terrestrial landscape (e.g. see references in Tiedemann et al. 1979). Even less research has been completed on stream systems within burned landscapes (e.g. Johnson and Needham 1966, Albin 1979) and little attempt has been made regarding the long-term (>10 years) implications of fire on stream systems. For a number of reasons, most studies examining the effects of fire on streams have concentrated efforts to <10 years following wildfire (Minshall and Robinson 1992). These reasons include the sporadic nature of fires, the tendency to treat fires as short-term crises rather than regularly recurring phenomena, and short-comings in organization (e.g. frequent transfer of personnel) and funding of government agencies responsible for watershed management. Furthermore, the opportunity to collect >10 year postfire data from study sites with short-term data sets already available was not present.

In 1979, following the 26,000 ha Mortar Creek Fire in central Idaho, we began a study to document the changes induced by wildfire on streams of various sizes in the Middle Fork of the Salmon River within the Frank Church River-of-no-Return Wilderness. At the time, this fire was one of the largest in the Intermountain Region during this century (Minshall et al. 1992). The findings from various aspects of this study have generated a number of project reports and journal articles documenting some of the short-term (<10 years) effects of the fire (e.g. Minshall et al. 1981, Minshall et al. 1989, Minshall et al. 1990, Minshall et al. 1992, Richards and Minshall 1992, Robinson et al. 1994) . The present study extends these findings by comparing conditions found in 1994 (15 year post-fire) with those found in 1989 (10 year post-fire) on these same study streams.

Yankee Fork Study

With the recent intensive increase in mining activity at the Sunbeam Mine, concern was expressed about the potential impacts from these activities to Jordan Creek and lower Yankee Fork Creek downstream of the confluence with Jordan Creek. These impacts are primarily associated with increased sediment loading and loss of riparian vegetation in and along Jordan Creek resulting from the widening of the adjacent dirt road and related increased truck traffic to the mine. The study compared reaches on Jordan and lower Yankee Fork Creeks with sites on the West Fork of Yankee Fork and upper Yankee Fork Creeks.

Mortar Creek Study Sites

The study was based on 10 streams accessed primarily by trail. Geology of the area is comprised of Challis Volcanics (Eocene age) intruded by the Castro Pluton phase (Tertiary age) of the Idaho Batholith (Ross 1934). Five streams were located within the fire perimeter and five proximal streams outside the perimeter were used as reference sites (Table 1). Streams ranged in size from 1st through 5th order and 1 through 262 links. Streams were paired by size (links), although Marble Creek was about 2x the size of L. Loon in terms of links. Study site elevations ranged from 1286 m (L. Loon) to 1414 m (Indian).

The climate of the area is considered semi-arid, with most precipitation occurring in winter. Annual precipitation ranges from 38 to 100 cm depending on elevation (Minshall et al. 1981). Vegetation at the study sites include: alder (Alnus), water birch (Betula occidentalis), black poplar (Populus trichocarpa), aspen (Populus tremuloides), and willow (Salix). Conifers are found in moister areas of the adjacent slopes but rarely in high densities. These include: subalpine fir (Abies lasiocarpa), whitebark pine (Pinus albicaulis), douglas fir (Pseudotsuga menziesii), and ponderosa pine (Pinus ponderosa). The predominant shrub in the area is sagebrush (Artemisia).

Table 1. Selected physical characteristics and coordinates of the Mortar Creek Fire Study sites.

STREAM	ORDER	LINK	DISCHARGE (m^3/s)		ELEV (m)	LONGITUDE	LATITUDE
			1989	1994			
REFERENCE STREAMS							
TEAPOT	1	1	0.002	.01	1390	115°02'37"	44°45'10"
PUNGO	2	10	0.04	.04	1396	115°04'21"	44°45'56"
EF INDIAN	3	12	0.09	.04	1413	115°05'32"	44°46'15"
INDIAN	4	89	0.31	.92	1414	115°06'27"	44°46'02"
MARBLE	5	262	1.0	1.01	1344	115°01'00"	44°44'38"
BURN STREAMS							
CHAR	2	2	0.004	.002	1356	114°56'08"	44°42'31"
LITTLE	2	7	0.07	.10	1408	114°59'03"	44°43'11"
WFL LOON	4	24	0.10	.10	1341	114°56'03"	44°42'35"
EFL LOON	4	105	1.5	.34	1329	114°55'58"	44°42'35"
L LOON	5	132	2.0	.47	1286	114°56'17"	44°43'45"

Methods

Physical and chemical measures recorded for each study site are found in Table 2. Sample type was referred to as Point (P), Transect (T), or Random (R) through a linear reach of stream. Point sampling was used to obtain data for a specific location or where one sample was sufficient to characterize the study reach. Transect sampling was used where factors were expected to vary across the stream in a regular manner. Random sampling was used where a number of samples were required to characterize an entire reach. Methodology was the same for the Mortar Creek study and the Yankee Fork study.

Most of the methods used are routine in stream ecology and are described in detail in standard reference sources (Weber 1973, Greeson et al. 1977, Lind 1979, Merritt and Cummins 1984, APHA 1992). Additional details are provided in the references located with Table 2, although methods for collecting benthic macroinvertebrates are described in Platts et al. (1983). Procedural methods also are outlined in Table 2. Other methods will be addressed in the text.

Results

Mortar Creek Study

Physical and Chemical Changes: Little change occurred in measured physical and chemical parameters in burn or reference streams from 1989 to 1994. Stream gradient was greater (8-18%) in the smaller streams than in the larger streams (1-2%) (Table 3). A notable decrease in water temperature was recorded in most burn streams from 1989 to 1994. The exceptions were Char Creek, the smallest burn tributary examined, and mouth L. Loon. Median and mean substrate size was comparable between burn and reference streams, although 1994 values tended to be 2x the median size of 1989 values in the larger streams.

Values of pH were similar between burn and reference streams

Table 2. Summary of variables, sampling methods, and analytical procedures used in the study.

Variable	Type*	Sampling Method	Analytical Method	Reference
A. Physical				
Temperature	P	Field measurement	Digital thermometer	
Substratum Size	R	Measure x-axis of 100 randomly selected substrata	Calculate mean substratum size	Leopold 1970
Substratum Embeddedness	R	Visual estimation on 100 randomly selected substrata	Calculate mean substratum embededdness	Platts et al. 1983
Stream Width	T	Measure bank-full width using a nylon meter tape	Calculate mean stream width	Buchanan and Somers 1969
Stream Depth	R	Measure water depth at the 100 randomly choosen substrata	Calculate mean water depth	
Discharge	T	Velocity/depth profile Velocity measured with a small C-1 Ott meter	Q=WxDxV; where Q=discharge, W=width, D=depth, and V=vel	Bovee and Milhous 1978
B. Chemical				
Conductivity	P	Field measurement	Temperature compensated meter (Orion model 126)	APHA 1992

* P=point measure; T=transect across stream; R=random throughout a defined reach.

Table 2 (cont.).

Variable	Type*	Sampling Method	Analytical Method	Reference
pH	P	Field measurement	Digital meter (Schott model CG837)	APHA 1992
Alkalinity	P	Single water sample	Methly-purple titration	APHA 1992
Hardness	P	Single water sample	EDTA titration	APHA 1992
C. Biological				
Invertebrates	R	Collect 5 samples using a Surber sampler	Remove invertebrates, identify, enumerate, and analyze community properties	Platts et al. 1983, Merritt and Cummins 1984
Periphyton	R	Collect samples from 5 individual substrata	Methanol extraction	Robinson and Minshall 1986
Benthic Organic Matter	R	Recovered from Surber samples	Determine AFDM	

* P=point measure; T=transect across stream; R=random throughout a defined reach.

Table 3. Percent slope and Delta C (difference between maximum and minimum temperatures) for 1989 and 1994 for the Mortar Creek Fire study sites. R=reference sites, B=burn sites.
*Note: substrate measures not recorded in 1989.

Site	Type	% Slope	Delta C	Delta C	Substrata		
					Median	Median	Mean
		1989	1989	1994	1988*	1994	1994
TEAPOT	R	18	9	8	6	18	20.3
CHAR	B	14	7	7	10	10	11.7
PUNGO	R	7	12	13	8	10	15.1
LITTLE	B	8	14	11	10	11	15.1
EF INDIAN	R	5	15	15	8	21	13.3
WFL LOON	B	8	17	11	10	13	17.5
INDIAN	R	1	23	19	9	20	24.8
EFL LOON	B	2	22	13	14	21	27.8
MARBLE	R	2	21	15	9	22	31.2
L LOON	B	5	18	20	12	25	33.0

Table 4. Water chemistry parameters for the study streams from samples collected in 1989 and 1990 or 1994.

SITE	Type	Total Hardness (mg/L CaCO3)		Alkalinity (mg/L CaCO3)		Specific Conductance (uS/cm @20C)		TDS*		pH
		1989	1990	1989	1990	1989	1994	1989	1994	1994
TEAPOT	R	39	45	40	37	74	82	48	53	8.1
CHAR	B	35	47	38	48	70	90	46	59	8.3
PUNGO	R	45	58	46	54	78	100	50	65	8.1
LITTLE	B	48	79	53	77	83	135	54	88	8.0
EF INDIAN	R	43	53	40	48	90	94	58	61	8.2
WFL LOON	B	37	44	37	52	75	98	49	64	8.2
INDIAN	R	34		37		79	85	52	55	8.2
EFL LOON	B	41	51	47	58	86	108	56	70	8.5
MARBLE	R	22		29		60	63	39	41	8.2
LLOON	B	41	53	46	57	95	105	62	68	8.6

*Estimated as 0.65X Specific Conductance

with a slight increase (.2 pH units) in the larger streams (Table 4). Specific conductance increased slightly from 1989 to 1994 in all sites, more pronounced in burn streams (10-52 μS/cm) than in reference streams (3-22 μS/cm). To provide background information, total hardness and alkalinity were determined for 1989 and 1990 with little change among years for burn or reference streams.

Little change was observed in channel morphology between 1989 and 1994 for most sites (Figs. 1-5). Essentially no change occurred in cross-sectional areas in the burn Char Creek site; whereas a large boulder slid into the channel in the respective reference Teapot Creek that resulted in a small amount of channel cutting (Fig. 1). No change in cross-sectional areas was observed in comparably sized Little (burn) and Pungo (reference) Creeks between study years (Fig. 2), or the WF L. Loon (burn) and EF Indian (reference) Creeks (Fig. 3).

EF L. Loon also displayed no change in channel profile between 1989 and 1994; whereas the reference site (Indian Creek) showed some aggrading and downcutting resulting from a debris dam altering flow paths within the channel at the location of the permanent transect (Fig. 4). Interestingly, L. Loon and Marble Creek, the largest of the paired study streams, showed some channel movement between 1989 and 1994. For example, L. Loon displayed cutting to the left bank; whereas the Marble Creek data indicated substantial aggrading (ca. 0.3 m) between study years (Fig. 5). The additional channel change at L. Loon may have resulted from a bridge being built downstream about 30 m from the permanent transect; although additional headcutting may still be occurring as a result of the fire.

Periphyton and Benthic Organic Matter: Mean periphyton biomass, as chlorophyll a and AFDM increased slightly in burn and reference streams from 1989 to 1994 (Table 5). Diatom assemblages were examined from six study sites in 1994 (Table 6). Achnanthedium minutissimum was predominant in the reference sites and the WF L. Loon. Cocconeis placentula var. lineata was prevalent in the burn sites and the reference site Teapot Creek. Char and Teapot Creeks had similar diatom assemblage structure.

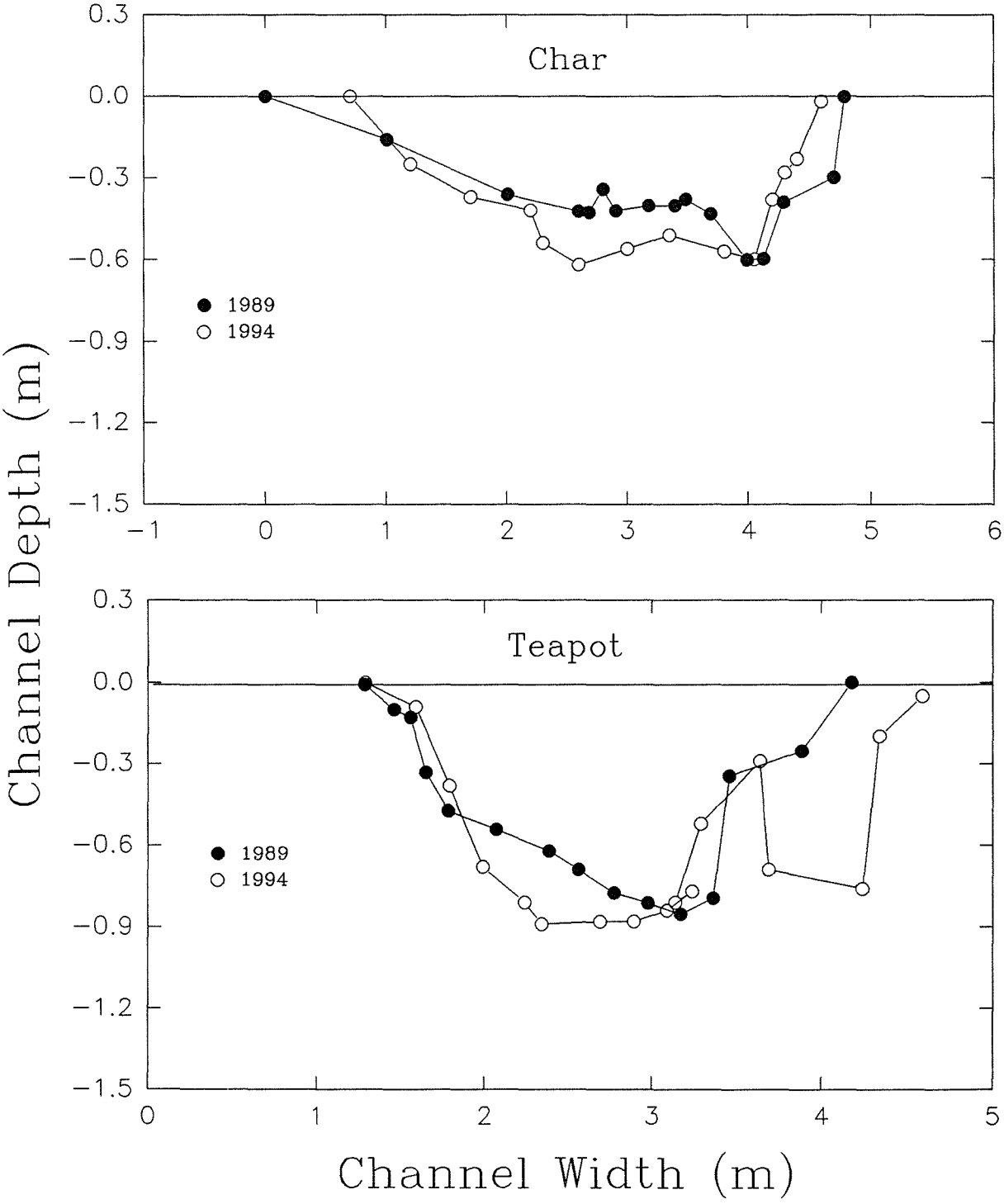

Fig. 1. Channel cross-section profiles for Char and Teapot Creeks during the years of study. Measures recorded from a permanently marked transect.

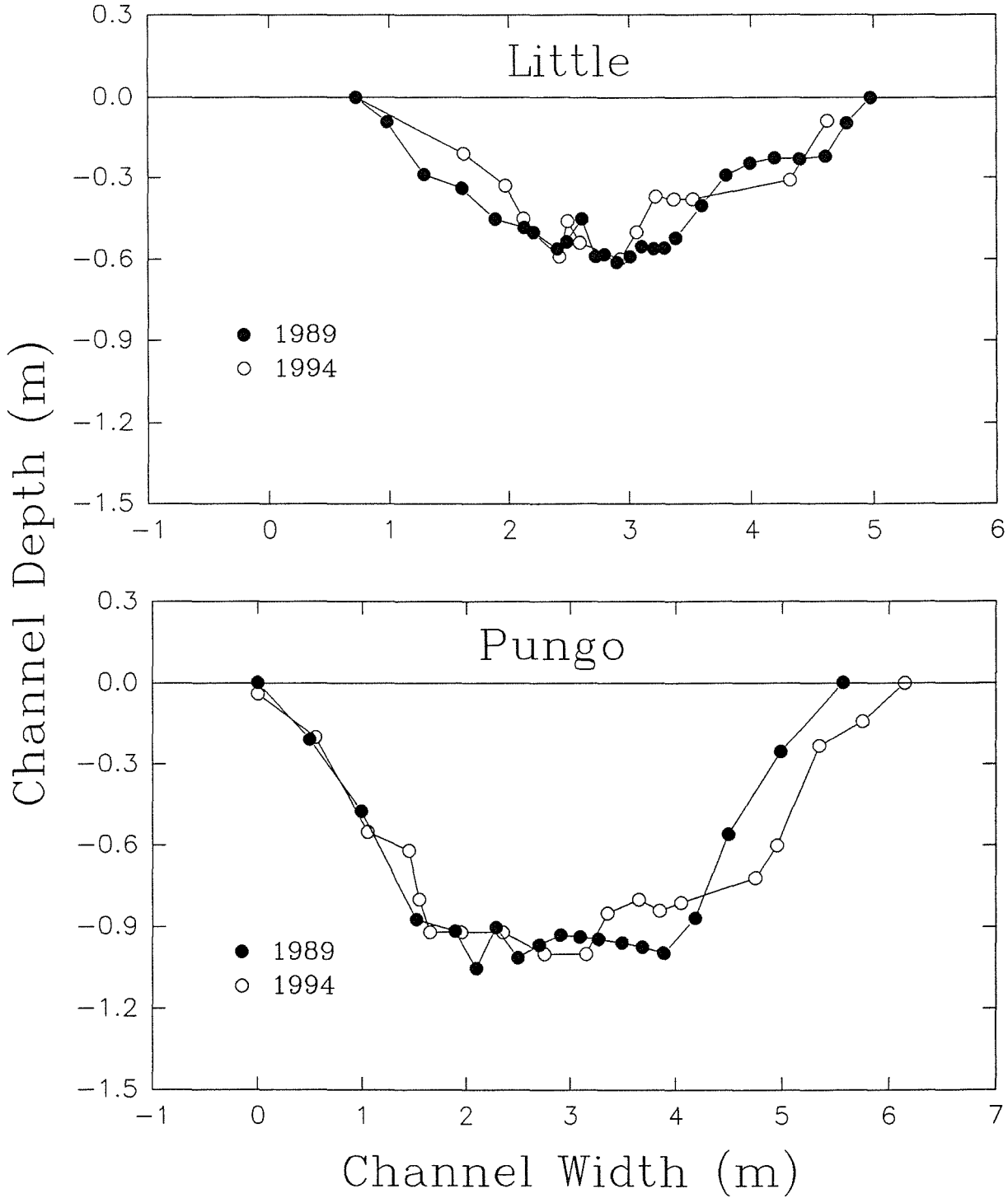

Fig. 2. Channel cross-section profiles for Little and Pungo Creeks during the years of study. Measures recorded at a permanently marked transect.

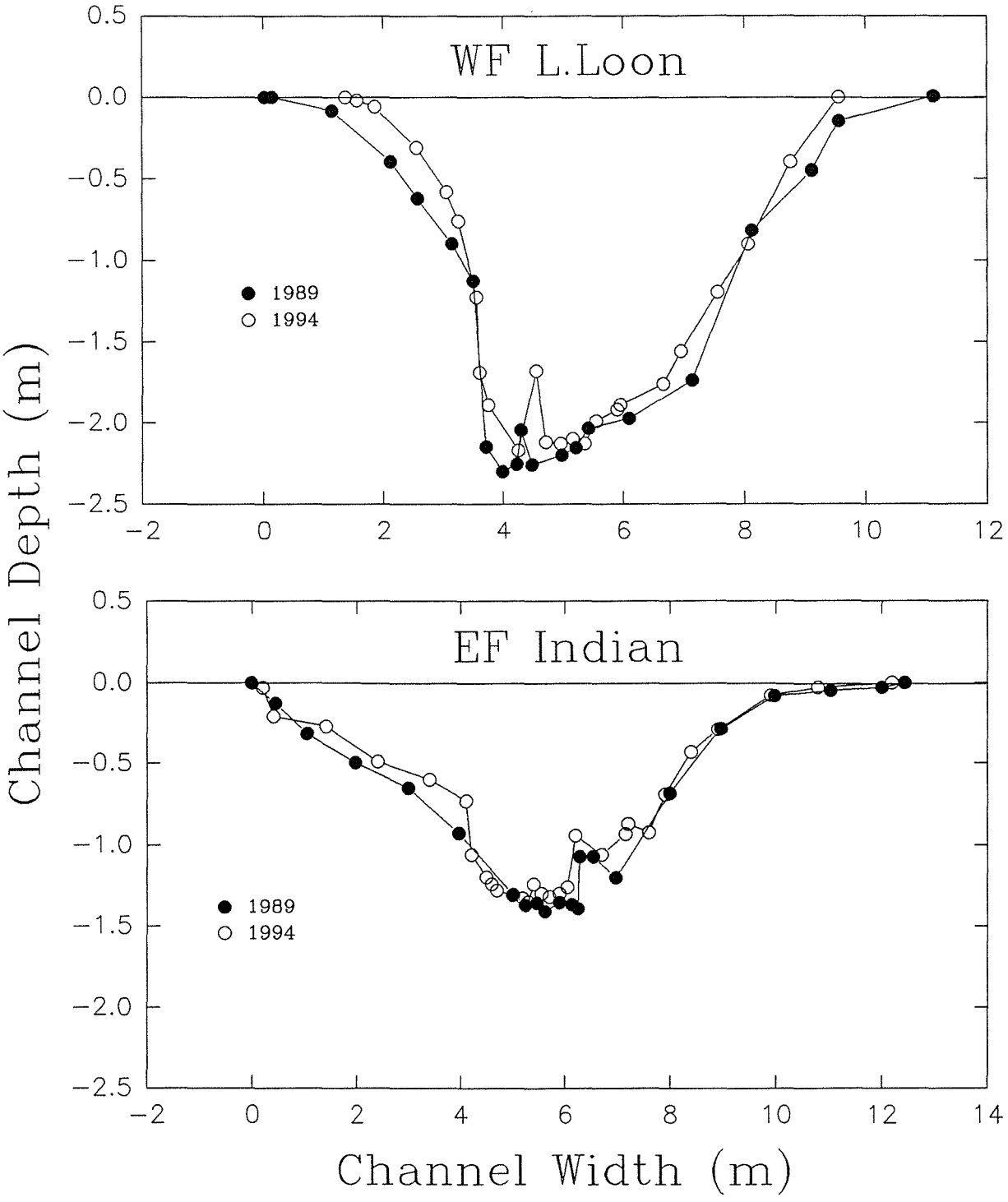

Fig. 3. Channel cross-section profiles for WF L.Loon and EF Indian Creeks during the years of study. Measures recorded at a permanently marked transect.

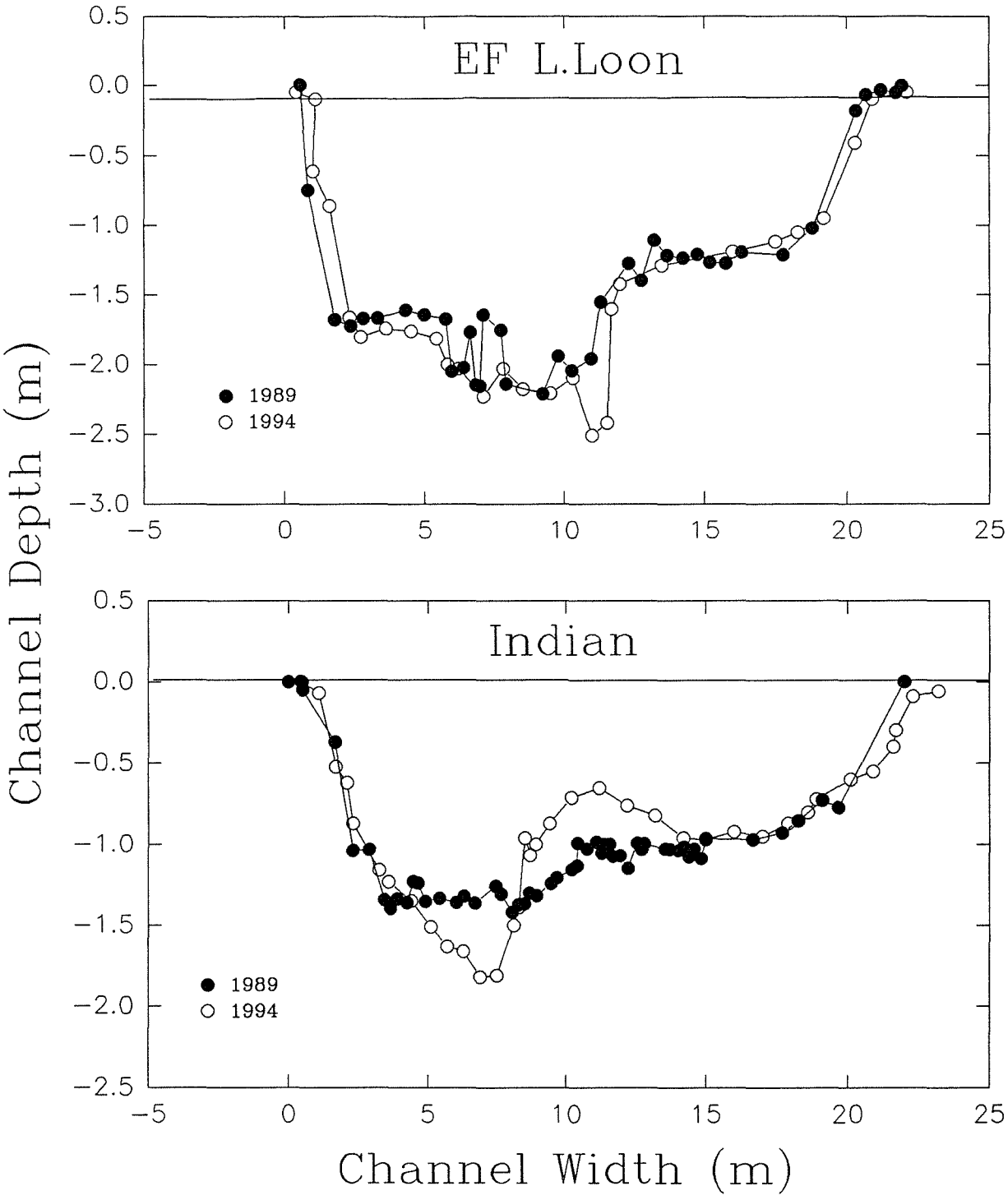

Fig. 4. Channel cross-section profiles for EF L.Loon and Indian Creeks during the years of study. Measures recorded at a permanently marked transect.

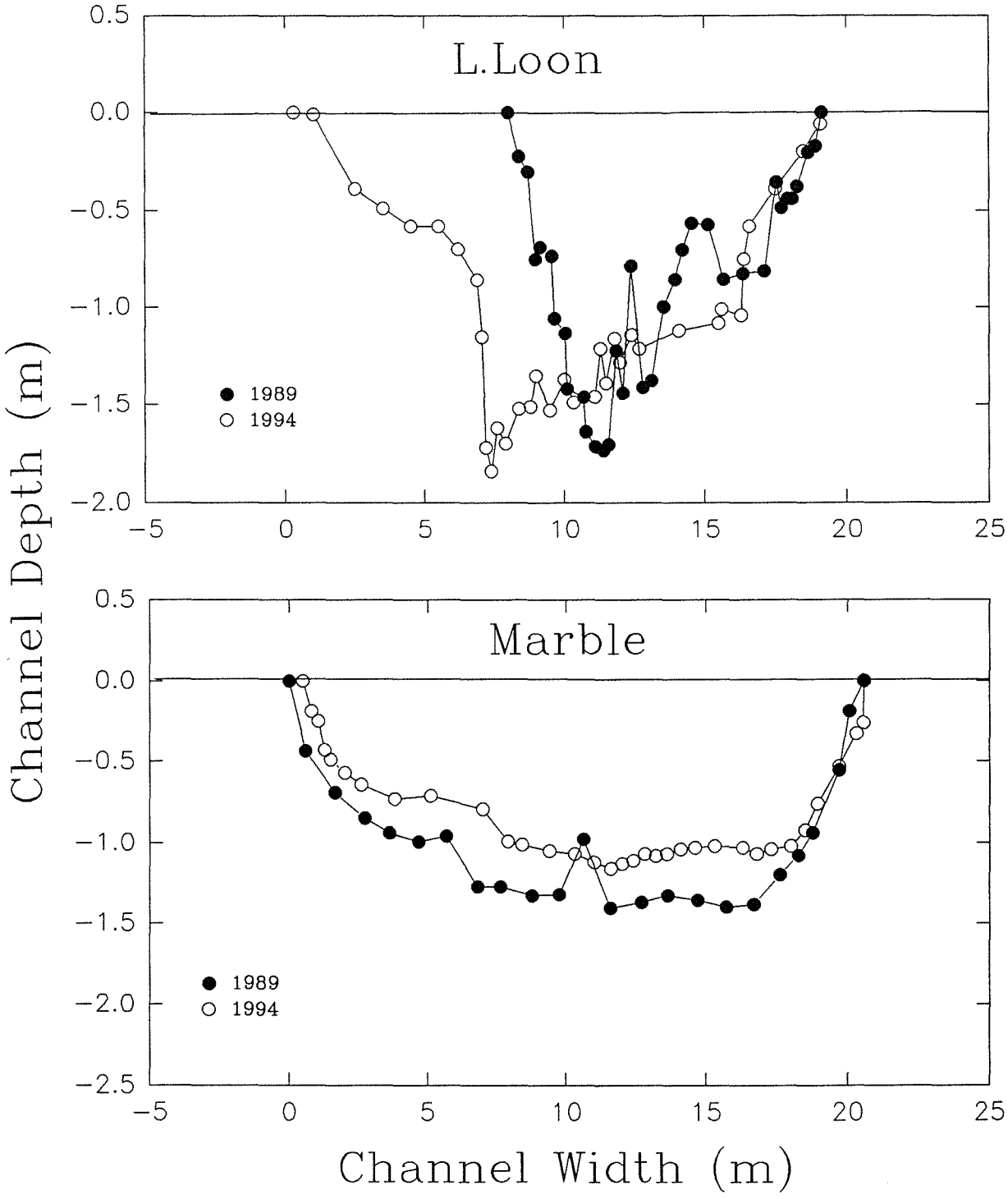

Fig. 5. Channel cross-section profiles for L.Loon and Marble Creeks during the years of study. Measures recorded at a permanently marked transect.

Table 5. Periphyton chlorophyll a (mg/m^2) and AFDM (g/m^2) values for July 1989 and July 1994 for the Mortar Creek Fire study sites. N=5 for each date and site. R=reference sites, B=burn sites.

Site	Type	Chlorophyll a				AFDM			
		1989		1994		1989		1994	
		mean	SD	mean	SD	mean	SD	mean	SD
TEAPOT	R	11	8	16	24	1.3	1.2	4.5	4.0
CHAR	B	4	2	29	23	0.3	0.1	3.1	2.1
PUNGO	R	1.4	3.4	29	17	0.2	0.1	6.3	1.7
LITTLE	B	1.6	0.8	35	27	0.3	0.3	6.7	3.9
EF INDIAN	R	1.2	0.5	8	3	0.2	0.1	3.5	1.1
WFL LOON	B	7.4	4.5	10	6	0.6	0.3	7.0	3.8
INDIAN	R	6.5	6.2	10	9	0.4	0.2	3.8	2.4
EFL LOON	B	9.7	9.1	15	10	0.6	0.4	4.9	2.6
MARBLE	R	3.7	2.4	13	10	0.6	0.4	4.5	1.4
L LOON	B	5.1	6.1	9	6	1.0	1.1	3.7	1.1

Table 6. Diatom assemblage structure from selected study streams sampled in 1994.

	Char (B)	Teapot (R)	Pungo (R)	WF L Loon (B)	EF Indian (R)	EF L Loon (B)
TOTAL VALVES COUNTED	984	1155	1150	1110	1046	1152
SPECIES RICHNESS	18	28	18	32	22	34
SIMPSON'S INDEX (C)	68	21	76	20	45	17
SHANNON'S (H',natural log)	0.79	1.99	0.67	2.14	1.33	2.34
Relative Abundance (%)						
Achnanthedium minutissimum	1.6	17.5	87.0	31.0	64.1	3.6
Cocconeis placentula var. lineata	81.9	36.7	5.0	5.6	17.0	33.0
Achnanthedium lanceolatum	10.2	18.7	0.5	7.6	7.1	1.9
Hannaea arcus	0.6	0.3	0.5	30.3	1.0	0.5
Navicula cryptocephala var. veneta	0.2	1.2	0.2	0.7	0.4	21.0
Navicula tripunctata	0.2	3.6	0.0	2.2	0.0	8.3
Cymbella minuta	0.0	0.5	0.7	6.3	1.5	0.9
Cocconeis placentula var. euglypta	1.2	6.4	0.0	0.5	0.2	1.0
Fragilaria vaucheriae	0.2	0.2	1.2	2.3	0.4	3.5
Diatoma hiemale	0.0	6.1	0.3	0.4	0.0	0.0
Epithemia sorex	0.0	0.0	0.0	0.0	0.0	6.1
Rhoicosphenia curvata	0.2	1.4	0.5	1.4	1.5	0.7
Gomphoneis herculeana	0.0	0.0	1.9	1.4	1.0	1.0
Nitzschia paleacea	0.0	0.0	0.0	0.0	0.0	5.2
Nitzschia hantzschiana	0.2	1.4	0.0	0.4	0.0	3.0
Nitzschia dissipata	0.0	0.0	0.0	2.2	0.0	1.4
Gomphonema clevei	0.0	0.0	0.5	0.2	2.3	0.2
Diatoma hiemale var. mesodon	0.8	1.4	0.2	0.2	0.2	0.0
Epithemia turgida	0.0	0.2	0.0	0.0	0.8	1.6
Nitzschia inconspicua	0.2	0.0	0.0	0.0	0.0	2.1

The diatom assemblages appear to be following the expected patterns in recovery; i.e. recovery of these primary producers in concert with changes and recovery of adjacent riparian zones. Achnanthedium minutissimum is expected to become predominant in the burn streams over time.

The amount of benthic organic matter decreased by half in Teapot Creek, but remained unchanged in Char in the two sampling years (Table 7). Mean BOM decreased by two-thirds in reference Pungo Creek, and was unchanged in Little Creek (burn) between years. BOM levels remained essentially unchanged in the larger study streams. The percent charcoal of the BOM increased in all sites from 1989 to 1994 being most pronounced in the burn streams of Little, WF L. Loon, and EF L. Loon Creeks. These data suggest some potential redistribution of instream sediments or additional input from terrestrial sources in these streams.

Transported organic matter (TOM) was collected in 1994 with no clear patterns exhibited between burn and reference streams (Table 7). Teapot and Char Creeks, and EF Indian and WF L. Loon Creeks had similar TOM, whereas TOM was higher in Little and EF L. Loon than in respective reference streams. In contrast, TOM was higher in Marble than in mainstem L. Loon perhaps reflecting the inherent turbidity of Marble Creek from an historical upstream sediment source.

Macroinvertebrate Assemblages: The mean density of macroinvertebrates was greater (ca. 5X) in 1994 than in 1989 for all study streams, with the exception of Char Creek (Table 8). However, little change was observed between study years in respect to the relative abundances of functional feeding groups. For example, no difference was shown between years among functional groups in Teapot, Pungo, Little, EF Indian, WF L. Loon, EF L. Loon, and Marble. Char Creek displayed an increase in the relative abundance of filterers and a corresponding decrease in miners. Indian Creek showed an increase in the relative abundance of scrapers and a decrease in predators in 1994 (Table 8). Gatherer abundance increased in 1994 to 20% of the assemblage, whereas miner abundance decreased by 13%.

Some differences still were evident in the relative

Table 7. Benthic organic matter (BOM), % charcoal of BOM, and transported organic matter (TOM) collected in the study streams in 1989 and 1994. N=5 (BOM), N=1 (TOM:1994). R=reference sites, B=burn sites.

SITE	Type	BOM (g/m2)				% Charcoal				TOM (mg/m3)
		1989		1994		1989		1994		1994
		mean	SD	mean	SD	mean	SD	mean	SD	
TEAPOT	R	105	56	48	15	15	10	22	2	37
CHAR	B	54	22	44	17	17	5	22	4	42
PUNGO	R	46	56	13	10	10	8	17	6	22
LITTLE	B	24	18	33	14	14	7	31	7	200
EF INDIAN	R	15	14	15	8	8	9	16	8	28
WFL LOON	B	27	25	26	13	4	10	32	12	10
INDIAN	R	3	4	12	6	6	13	10	0	84
EFL LOON	B	9	6	27	16	13	12	51	11	196
MARBLE	R	19	12	11	17	4	5	0	0	100
L LOON	B	16	7	11	8	3	3	11	2	13

Table 8. Mean density and relative abundance of functional feeding groups in study streams in 1989 and 1994. N=5.

Site	Year	Scrapers	Shredders	Gatherers	Filterers	Miners	Predators	Total
Teapot	89	1103	676	194	544	2695	610	5822
	94	3409	3312	729	879	7622	5339	21290
Char	89	838	2516	412	2831	2215	1274	10086
	94	161	3645	32	8512	375	1554	14279
Pungo	89	250	698	725	894	7181	1172	10920
	94	2701	708	4577	1672	11042	3248	23948
Little	89	213	1035	252	612	854	570	3536
	94	825	4170	1790	4116	2755	4888	18546
EF Indian	89	1332	773	973	164	2405	614	6261
	94	7890	3184	8512	740	10741	7676	38742
WFL Loon	89	1954	294	284	2095	2330	1402	8359
	94	15866	7643	2326	10388	18728	8769	63720
Indian	89	350	273	184	75	614	1018	2514
	94	5231	472	440	2809	5789	2605	17345
EFL Loon	89	3182	695	770	943	4451	1080	11121
	94	23080	2776	9830	8094	19060	3216	66057
Marble	89	245	154	157	271	811	260	1898
	94	5296	504	6314	3184	11277	6528	33103
L Loon	89	2814	290	320	567	4029	604	8624
	94	10816	858	5832	568	10055	1629	29759
Relative Abundance (percent)								
Teapot	89	19	12	3	9	46	10	
	94	16	16	3	4	36	25	
Char	89	8	25	4	28	22	12	
	94	1	26	0	60	3	11	
Pungo	89	2	6	7	8	66	11	
	94	11	3	19	7	46	13	
Little	89	6	29	7	17	24	16	
	94	4	22	10	22	15	26	
EF Indian	89	21	12	16	3	38	10	
	94	20	8	22	2	28	20	
WFL Loon	89	23	4	3	25	28	17	
	94	25	12	4	16	29	14	
Indian	89	14	11	7	3	24	40	
	94	30	3	3	16	33	15	
EFL Loon	89	29	6	7	8	40	10	
	94	35	4	15	12	29	5	
Marble	89	13	8	8	14	43	14	
	94	16	2	19	10	34	20	
L Loon	89	33	3	4	7	47	7	
	94	36	3	20	2	34	5	

abundances of functional groups between stream pairs for both sampling years (Table 8). For example, scrapers and miners were under-represented in the smaller burn streams, whereas shredders and filterers had higher relative abundances in these smaller burn streams. Reference EF Indian had a greater abundance of gatherers than WF L. Loon. Further, scraper relative abundance was higher in L. Loon than in the respective reference Marble Creek.

The biomass of macroinvertebrates also increased in 1994 in all study streams except Char Creek (Table 9). This increase was most evident in Little, EF Indian, WF L. Loon, Indian, and Marble Creeks, with about a 10X greater biomass being seen in 1994. The relative biomass of functional feeding groups between paired streams was quite similar, e.g. Char and Teapot, WF L. Loon and EF Indian, and EF L. Loon and Indian Creeks (Table 10). Exceptions were Pungo and Little Creeks, where Pungo Creek had greater relative biomass of scrapers and gatherers and fewer shredders. Further, Marble Creek exhibited greater relative biomass of shredders and filterers, but less biomass of predators, miners and scrapers than L. Loon Creek.

Common taxa also showed high similarity (among paired streams) in 1994 (Table 11). For example, most paired streams shared at least six of the top 10 most abundant taxa by numbers. Some of the differences were the greater abundance of ostracods in Char than in Teapot, and the greater abundance of Oligochaeta in Teapot. In respect to the Little and Pungo pair, Yoroperla brevis, Ephemerella infrequens, Micrasema, and Paraleptophlebia were more abundant in Little than Pungo; whereas chironomids and Drunella doddsi were more common in Pungo than Little. The WF L. Loon had greater abundance of Simulium than its respective EF Indian, whereas elmids were more common in EF Indian. The major difference between EF L. Loon and Indian was the predominance of Rhithrogena robusta in Indian. L. Loon showed a greater abundance of Cinygmula, and Zapada than Marble Creek, whereas Heptagenia, Heterlimnius, Simulium, and Brachycentrus were more common in Marble Creek than L. Loon Creek. Both Simulium and Brachycentrus are members of the filtering functional group.

Table 9. Absolute biomass (mg/m^2) and standard deviations of macroinvertebrate functional feeding groups for the Mortar Creek burn (B) sites and reference (R) sites for 1989 and 1994.

Station	Type	Year	Total Biomass	Scrapers mean	SD	Shredders mean	SD	Gatherers mean	SD	Filterers mean	y	Miners mean	SD	Predators mean	SD
Teapot	R	'89	1024	182	90	227	272	63	64	39	26	157	63	356	192
		'94	5833	358	28	1310	194	492	86	233	31	636	210	2804	277
Char	B	'89	2795	109	53	769	583	56	49	131	131	100	64	1630	1690
		'94	2277	24	3	733	100	78	14	239	51	24	6	1181	114
Pungo	R	'89	1804	180	211	123	128	181	115	123	198	753	583	444	197
		'94	5413	1831	166	51	8	740	83	57	14	1013	328	1722	127
Little	B	'89	668	82	72	169	100	27	24	53	83	165	112	172	150
		'94	6122	86	7	1294	248	132	12	738	145	1012	423	2861	374
EFIndian	R	'89	613	161	156	31	14	155	123	39	62	95	48	132	84
		'94	8753	2195	264	410	79	1562	141	655	145	629	182	3302	274
WFLLoon	B	'89	1209	244	228	92	68	168	107	192	209	132	57	381	136
		'94	21543	5702	559	759	96	984	139	7323	1409	2549	787	4226	366
Indian	R	'89	207	32	34	22	25	54	70	25	24	28	16	46	47
		'94	2096	493	44	30	4	104	9	394	49	276	77	799	62
EFLLoon	B	'89	1868	314	213	174	230	368	282	243	425	234	88	535	74
		'94	11500	3379	340	551	110	2135	176	453	77	2159	497	2822	316
Marble	R	'89	170	29	21	11	8	22	15	44	26	32	10	32	29
		'94	14155	396	37	6927	1500	1214	116	1736	381	1142	186	2741	291
MFLLoon	B	'89	1457	231	91	15	23	79	37	78	81	422	184	632	358
		'94	4582	1195	127	107	21	797	107	79	12	803	246	1601	195

Table 10. Relative biomass (as %) of macroinvertebrate functional feeding groups for the Mortar Creek burn (B) sites and reference (R) sites for 1989 and 1994.

SITE	Type	Year	Scrapers %	Shredders %	Gatherers %	Filterers %	Miners %	Predators %
TEAPOT	R	'89	18	22	6	4	15	35
		'94	6	22	8	4	11	48
CHAR	B	'89	4	27	2	5	4	58
		'94	1	32	3	11	1	52
PUNGO	R	'89	10	7	10	7	42	24
		'94	32	1	13	1	18	30
LITTLE	B	'89	12	25	4	8	25	26
		'94	1	21	2	12	17	47
EFINDIAN	R	'89	26	5	25	6	16	21
		'94	25	5	18	7	7	38
WFLLOON	B	'89	20	7	14	16	11	31
		'94	26	4	5	34	19	20
INDIAN	R	'89	14	10	24	11	12	20
		'94	24	1	5	19	13	38
EFLLOON	B	'89	17	9	20	13	12	29
		'94	29	5	19	4	19	25
MARBLE	R	'89	17	7	13	26	18	19
		'94	3	49	9	12	8	19
MFLLOON	B	'89	16	1	5	5	29	43
		'94	26	2	17	2	18	35

Table 11. Most common taxa found in study streams in 1994 based on density.

BURN SITES

Char	Mean	Percent
Ostracoda	1644	58
Yoroperla brevis	375	13
Zapada	349	12
Turbellaria	217	8
Chironomidae	73	3
Brachycentrus	36	1
Hydracarina	30	1
Suwallia	26	1
Baetis bicaudatus	15	1

Little		
Ostracoda	802	22
Turbellaria	757	20
Oligochaeta	459	12
Yoroperla brevis	354	10
Ephemerella infrequens	176	5
Micrasema	163	4
Paraleptophlebia	150	4
Heterlimnius	129	3
Zapada	103	3

WF L. Loon		
Chironomidae	2982	24
Baetis bicaudatus	2485	19
Simulium	1617	13
Zapada	1246	10
Oligochaeta	763	6
Turbellaria	637	5
Cinygmula	459	4
Hydracarina	455	4
Heterlimnius	373	3

EF L. Loon		
Baetis bicaudatus	3355	25
Chironomidae	1934	15
Oligochaeta	1683	13
Prosimulium	1396	11
Optioservus	1282	10
Cinygmula	759	6
Zapada	540	4
Chelifera	236	2
Epeorus	227	2

L. Loon		
Baetis bicaudatus	1801	30
Chironomidae	1390	23
Optioservus	1108	19
Oligochaeta	607	10
Cinygmula	266	4
Zapada	142	2
Hydracarina	118	2
Isoperla	64	1

REFERENCE SITES

Teapot	Mean	Percent
Oligochaeta	1216	29
Turbellaria	791	19
Baetis bicaudatus	566	13
Zapada	364	9
Chironomidae	302	7
Yoroperla brevis	266	6
Paraleptophlebia	109	3
Brachycentrus	88	2
Simulium	62	1

Pungo		
Oligochaeta	1788	37
Heterlimnius	765	16
Chironomidae	418	9
Ostracoda	326	7
Turbellaria	189	4
Drunella doddsi	157	3
Suwallia	126	3
Zapada	101	2
Rhyacophila vagrita	90	2

EF Indian		
Oligochaeta	1203	16
Heterlimnius	885	11
Chironomidae	855	11
Cinygmula	626	8
Baetis bicaudatus	611	8
Optioservus	459	6
Hydracarina	433	6
Zapada	382	5
Turbellaria	375	5

Indian		
Chironomidae	729	21
Rhithrogenia robusta	491	14
Baetis bicaudatus	410	12
Oligochaeta	397	11
Hydracarina	375	11
Simulium	364	11
Cinygmula	120	3
Arctopsyche	92	3
Zapada	88	3

Marble		
Oligochaeta	1211	18
Chironomidae	1015	15
Hydracarina	858	13
Optioservus	669	10
Baetis bicaudatus	461	7
Heptagenia	341	5
Heterlimnius	259	4
Simulium	253	4
Brachycentrus	249	4

Yankee Fork Study

Physical and Chemical Measures: Study sites (Fig. 6) were located on reaches of similar elevation, ranging from 1850 m at L. Yankee Fork to around 2000 m at Jordan Creek (Table 12). Discharge was lowest at Jordan Creek and highest at L. Yankee Fork with half of its flow derived from Upper Yankee Fork and half from the West Fork of Yankee Fork. Stream slopes ranged from 1 (U. Yankee) to 3% (Jordan). Jordan Creek had a substantially reduced riparian width resulting from the recent road development associated with present mining activities. The recent mining activities also are evident in the overall low habitat assessment score of this site. Here, U. Yankee Fork had the highest score and L. Yankee and WF Yankee displaying similar habitat scores.

Chemically, Jordan Creek displayed higher ion concentrations than Yankee Fork sites and U. Yankee Fork exhibited the lowest ion (conductance, hardness, or alkalinity) values (Table 12). For example, U. Yankee Fork showed values that were half those found in WF Yankee and Lower Yankee Fork suggesting the higher values in L. Yankee are derived from streams draining the western side of the catchment such as WF Yankee and Jordan Creeks. Values for pH were comparable among sites, all being around 8.3. Field measured nutrient levels (NO_3 and PO_4) also were similar among sites, except that nitrate concentrations were noticeably greater (ca. 4X) in L. Yankee than the other sites. Phosphorus levels were highest in U. Yankee Fork.

Physically, Jordan Creek exhibited higher water temperatures than what would be expected for similarly sized intermountain streams and probably reflect the loss of riparian vegetation (Table 12). However, stream temperatures in Jordan Creek were still relatively low being 12.4 C. Bankfull widths reflected general stream size with Jordan Creek displaying the shortest width (6.6 m) and L. Yankee the greatest (20.1 m). Mean water depth was less than 35 cm in all sites with Jordan Creek having the lowest. Width:Depth ratios were identical among study sites, except that U. Yankee Fork had a W:D ratio one-half that of the other sites.

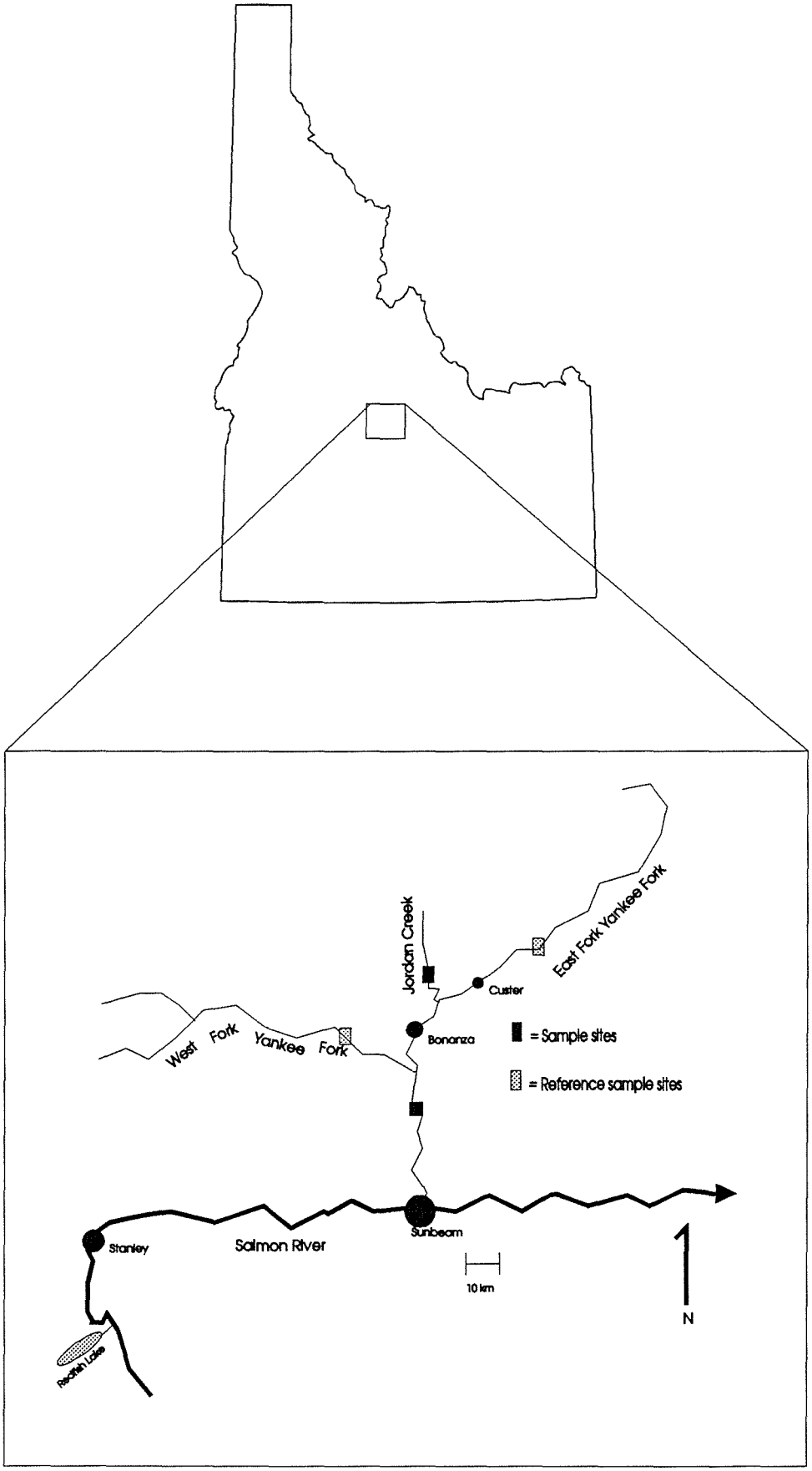

Figure 6. Sample sites of the Yankee Fork study.

Table 12. Site characteristics for study streams of the Yankee Fork.
Values in () are standard deviations. CV=Coefficient of Variation.

Parameter	Jordan	L. Yankee	U. Yankee	WF Yankee
GENERAL				
Elevation (m)	2000	1850	1970	1950
Discharge (m3/s)	0.02	0.75	0.34	0.3
slope (%)	3	2	1	2.5
Riparian Width (m)	1.5	25	15	
Habitat Assessment Score	65	125	149	121
CHEMICAL				
pH	8.4		8.3	8.3
Specific Conductance (uS/cm)	103	74	39	70
Total Hardness (mg/L CaCO3)	56	34	16	38
Alkalinity (mg/L CaCO3)	69	48	45	48
Phosphorus (mg/L PO4)	0.03	0.05	0.18	0.05
Nitrogen (mg/L NO3)	0.07	0.35	0.08	0.09
PHYSICAL				
Temperature (C)	12.4	13.9	9.9	7.7
Turbidity	Clear	Clear	Clear	Clear
Bankfull Width (m)	6.6	20.1	10.8	13.7
Water Width (m)	3.4	16.1	7.4	9.5
Depth (cm)	10(8)	31(18)	33(34)	21(13)
Depth CV	0.82	0.57	1.03	0.64
W:D Ratio	66	65	33	65
Substrate Size (cm)	13(10)	18(12)	9.9(8.7)	16(9.5)
Substrata (median)	11	14	7	15
Substrate Size CV	0.77	0.69	0.88	0.58
Embeddedness (%)	46(35)	33(30)	48(41)	47(72)
Embeddedness CV	0.76	0.89	0.85	1.51
ORGANIC MATTER				
Chlorophyll a (mg/m2)	4.65(2.78)	8.79(3.59)	2.35(2.02)	5.35(2.63)
Periphyton AFDM (mg/m2)	10.91(3.34)	11.11(2.38)	5.70(2.18)	8.38(3.43)
Benthic Organic Matter (g/m2)	1.31(0.56)	2.41(1.61)	2.384(2.48)	3.03(2.89)
B:C Ratio	2.34	1.26	2.42	1.56

Average and median substratum size was comparable among sites (10-18 cm), with U. Yankee Fork exhibiting the smallest substrate size (Table 12). Coefficients of variation for substrata were relatively similar among sites. Substrate embeddedness values also were similar among sites ranging from 33% at L. Yankee Fork to 48% at U. Yankee Fork. West Fork Yankee Fork exhibited the highest CV for embeddedness (151%).

Lower Yankee Fork had the highest periphyton chlorophyll a levels (8.8 mg/m^2) and U. Yankee Fork the lowest (2.4 mg/m^2) (Table 12). In contrast, Jordan and L. Yankee Fork Creeks showed the highest periphyton biomass in terms of AFDM, with U. Yankee Fork having the lowest AFDM. Periphyton AFDM to chlorophyll a ratios were comparable among sites. Benthic organic matter was essentially equal among sites, ranging from 1.31 g/m^2 at Jordan Creek to 3.03 g/m^2 at WF Yankee Fork Creek.

Macroinvertebrate Differences: Total number of macroinvertebrate taxa collected was greater by 10 taxa in U. and WF Yankee Fork than in Jordan and L. Yankee Fork Creeks (Fig. 7). However, mean taxa richness was similar among sites. The mean density of macroinvertebrates was highest at Jordan and WF Yankee Fork Creeks and lowest at L. and U. Yankee Fork (Fig. 7). Mean biomass also was highest at Jordan Creek, although values were comparable among sites.

Density and biomass of predators and gatherers were highest in Jordan Creek, and the biomass of filterers was greater in Jordan Creek than the other sites (Fig. 8). Scrapers and shredders displayed the greatest density and biomass in U. Yankee Fork, and predators also were abundant in U. Yankee Fork. The density of miners were highest in Jordan and WF Yankee Fork Creeks, although the biomass of miners was highest in L. Yankee Fork Creek.

Miners comprised the greatest percent of functional feeding group density in Jordan, L. Yankee Fork, and WF Yankee Fork Creeks (Fig. 9). Scrapers were relatively more abundant in U. Yankee Fork than the other functional groups. The relative density of shredders was higher in U. Yankee Fork than the other sites. Gatherers and filterers displayed similar relative

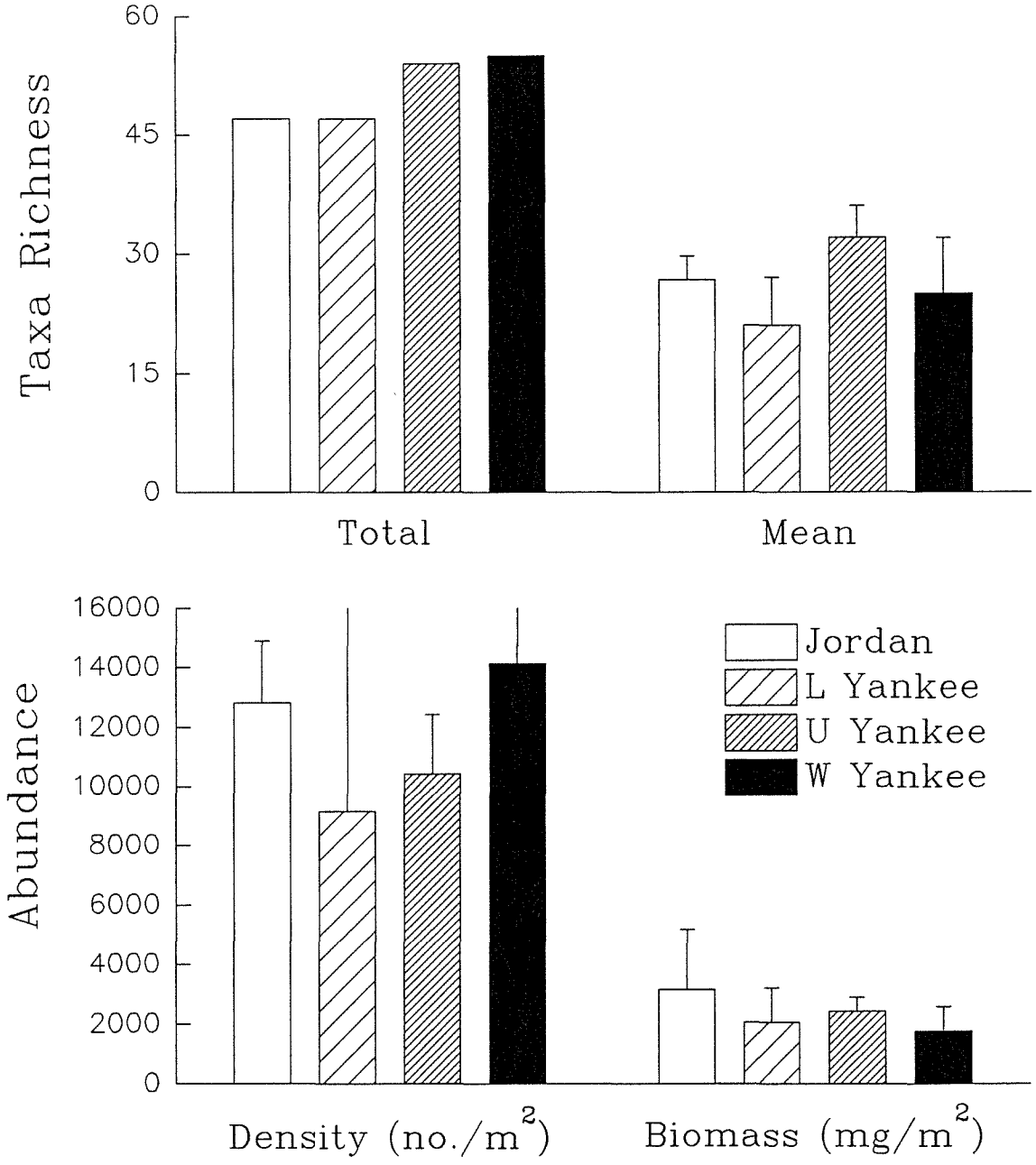

Fig. 7. Taxa richness by site and averaged by sample, and abundance as density and biomass. N=10, where error bars equal +1 SD.

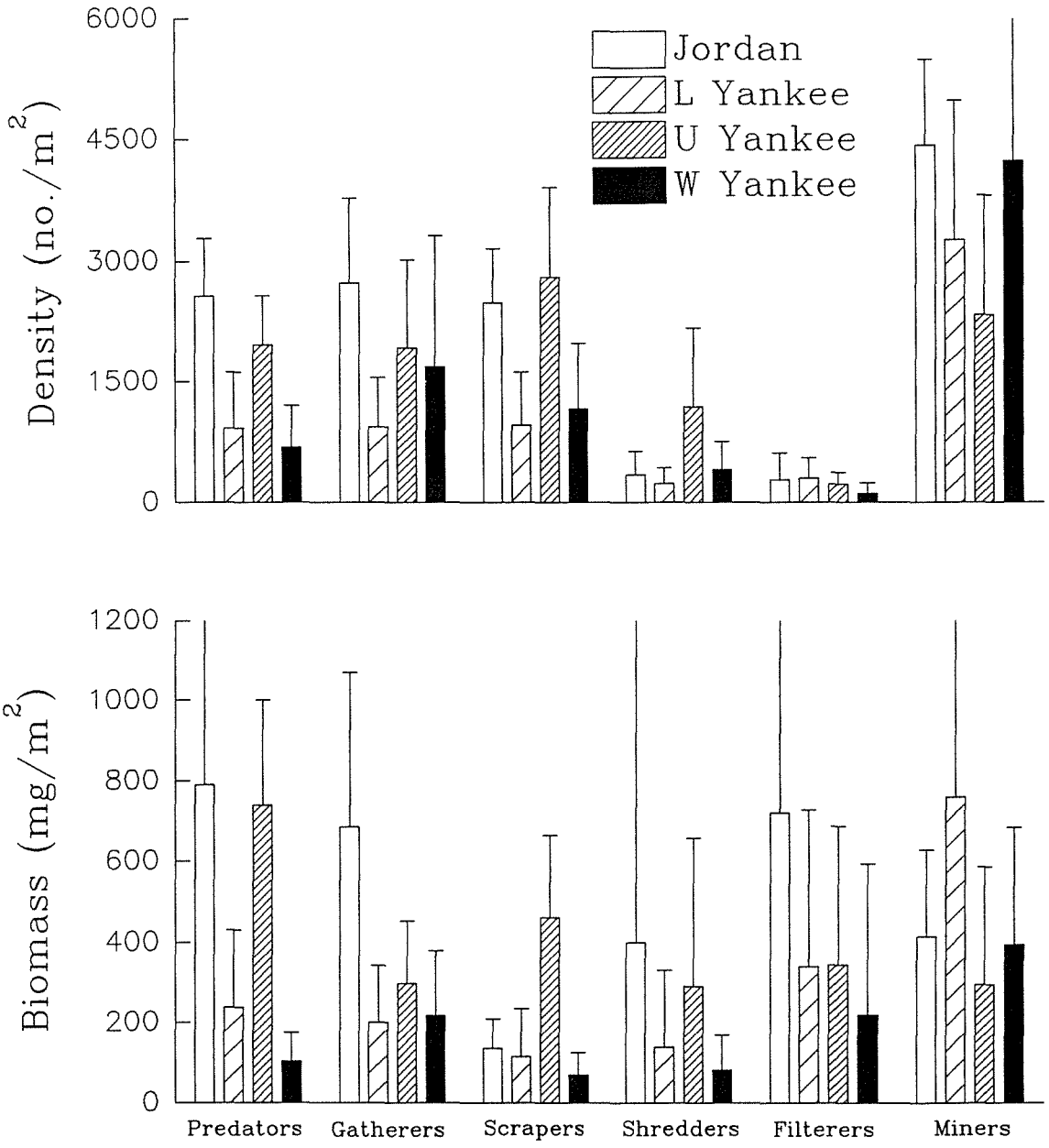

Fig. 8.. Density and biomass of functional feeding groups for Yankee Fork study sites. N=10, where error bars equal +1SD.

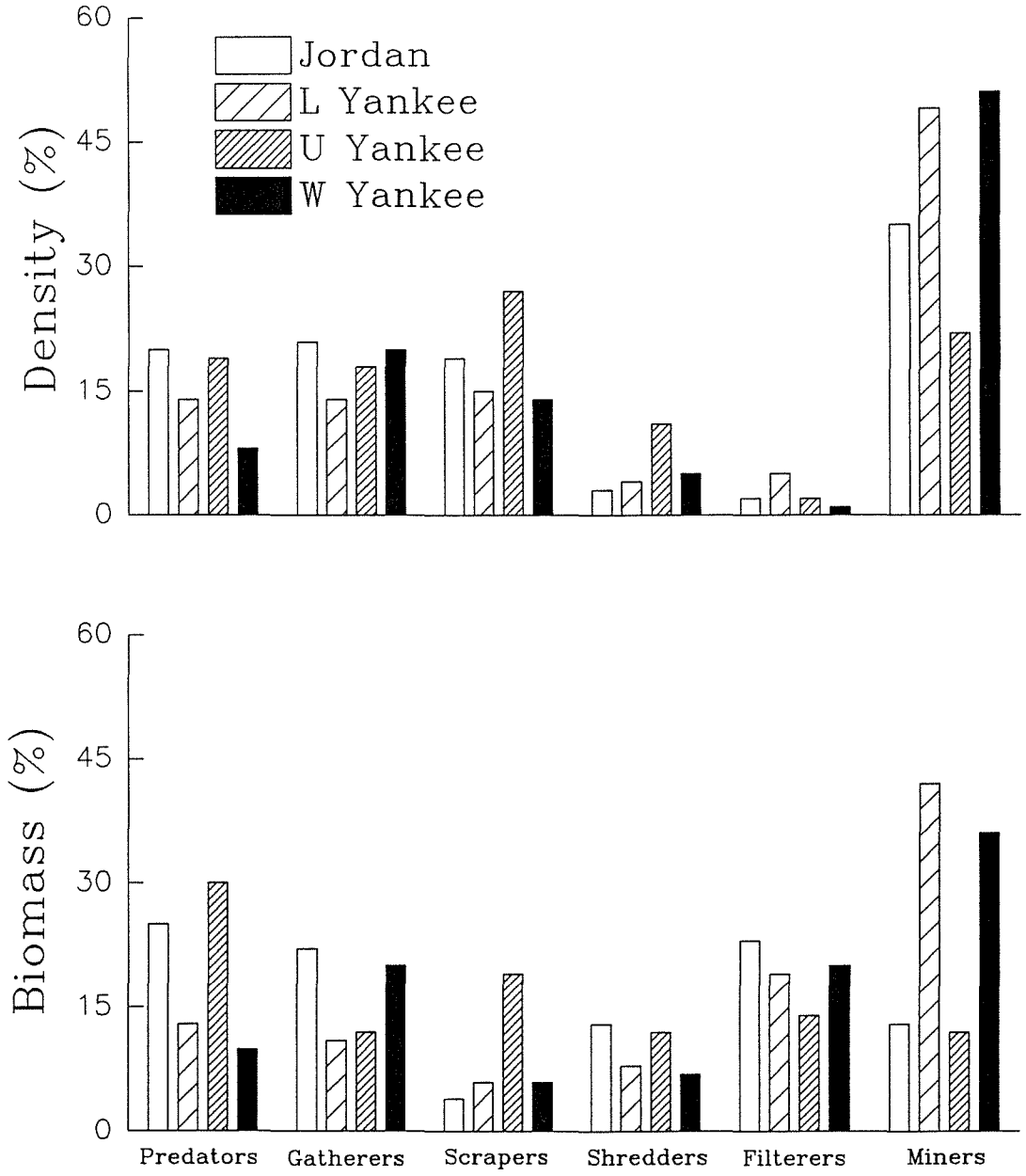

Fig. 9. Relative density and biomass of functional feeding groups for the Yankee Fork study sites.

densities among sites.

Miner relative biomass was highest in L. and WF Yankee Fork Creeks than in the other sites (Fig. 9). Predator relative biomass was highest in Jordan and U. Yankee Fork Creeks, and the relative biomass of scrapers was greatest in U. Yankee Fork Creek. Filterer relative biomass was substantially higher than the relative density measures.

Analysis of the relative abundance of the most common taxa found at each site revealed that chironomids were prevalent at all sites. However, U. Yankee Fork had the lowest percent (18.4%) and WF Yankee Fork the highest (48.8%) (Table 13). Eight of the 16 most common taxa were found at all sites. These taxa comprised >72% of the assemblage at Jordan (80%), L. Yankee Fork (80%), and WF Yankee Fork (72%), but only 54% of the assemblage at U. Yankee Fork Creek. Hydracarina and *Baetis bicaudatus* were common in Jordan Creek, Oligochaeta was common in L. Yankee Fork, *Baetis bicaudatus* and *Rhithrogena robusta* were relatively common in U. Yankee Fork, and *Ephemerella inermis* and *Baetis bicaudatus* were abundant in WF. Yankee Fork Creek. *Arctopsyche grandis* and *Apatania* were common in Jordan and L. Yankee Fork Creeks but not in U. and WF. Yankee Fork Creek. *Rhithrogena robusta* was uncommon in Jordan Creek but common in the other sites.

Discussion

Mortar Creek Study

Few differences were observed between 1989 and 1994 from paired burn and reference streams of the 1979 Mortar Creek fire study. For example, the only major channel change in this 5 year period was at mainstem L. Loon Creek which exhibited much lateral cutting. This channel change, however, may simply been a result of the new bridge installed downstream of the permanent transect location. However, another plausible explanation is that L. Loon Creek is experiencing major headcutting as a result of the fire's initial effect (1-5 yrs) of enhancing stream sediment loads along with dramatic channel downcutting.

Table 13. Relative abundance of the most common taxa collected in study streams.

Jordan	Percent	Lower Yankee Fork	Percent	Upper Yankee Fork	Percent	West Yankee Fork	Percent
Chironomidae	32.2	Chironomidae	33.4	Chironomidae	18.4	Chironomidae	48.8
Hydracarina	11.2	Oligochaeta	15.9	Baetis bicaudatus	10.3	Ephemerella inermis	11.4
Baetis bicaudatus	10.1	Antocha	7.9	Rhithrogena robusta	9.8	Baetis bicaudatus	9.7
Heptagenia	8.3	Hydracarina	7.3	Suwallia	7.0	Hydracarina	4.0
Antocha	8.0	Baetis bicaudatus	6.5	Ephemerella inermis	6.7	Ephemerella infrequens	3.6
Suwallia	5.9	Heptagenia	3.6	Ephemerella infrequens	5.6	Antocha	3.6
Heterlimnius	2.9	Suwallia	3.4	Hydracarina	4.4	Oligochaeta	2.4
Apatania	2.6	Ephemerella infrequens	3.0	Oligochaeta	3.9	Pericoma	1.5
Oligochaeta	2.3	Arctopsyche grandis	2.3	Heterlimnius	3.7	Heptagenia	1.4
Zapada	2.1	Apatania	2.1	Heptagenia	3.2	Suwallia	1.3
Pericoma	2.0	Heterlimnius	1.7	Paraleptophlebia	2.8	Paraleptophlebia	1.3
Ephemerella inermis	1.9	Turbellaria	1.4	Skwala	2.7	Rhithrogena robusta	1.1
Serratella tibialis	1.6	Epeorus albertae	1.4	Antocha	2.7	Heterlimnius	1.1
Arctopsyche grandis	1.3	Brachycentrus	1.2	Caudatella	2.3	Skwala	0.9
Skwala	1.3	Rhyacophila vaccua	1.0	Paraleuctra	1.9	Cinygmula	0.7
Paraleptophlebia	1.0	Rhithrogena robusta	1.0	Prostoia	1.7	Zapada	0.6

Water temperatures in burn streams were comparable to those of reference streams suggesting riparian vegetation is of adequate height for shading the surface of the burn streams. Interestingly, specific conductance was substantially higher in burn streams than reference streams in 1994 that was not evident in 1989. Transported organic matter also was greater in burn streams than in respective reference streams indicating additional subtle influences from the fire. Whether these effects are of biological relevance has yet to be determined, but suggest potential functional differences may exist between burn and reference streams.

The results show that the fire is still influencing the macroinvertebrate assemblages in smaller streams. For example, filterers and shredders were more abundant in the smaller burn streams than in respective reference streams, whereas miners and scrapers were more abundant in the smaller reference streams. These data suggest that food resources still may differ between burn and reference streams, as indicated by the higher seston levels in burn streams and the differences in the abundance of diatom taxa. Assemblage structure was amazingly similar between the larger burn and reference streams.

In summary, little physical change was evident between post-fire year 10 and 15. Smaller streams still seem to be influenced by the fire with burn streams having different assemblage structure than respective reference streams. The potential headcutting of L. Loon Creek may have dramatic effects in future years as the headcut moves upstream into smaller streams. Headcutting would result in major changes in channel morphology, a potential loss of riparian vegetation, increased sediment loads, and a consequent reset or shift in the structure and function of macroinvertebrate assemblages. This hypothesis emphasizes the long-term perspective necessary for assessing the influences of large-scale disturbances.

Yankee Fork Study

The most obvious influence of the increased mining activity on Jordan Creek was the loss of riparian vegetation causing an

increase in solar radiation reaching the stream. This effect was evident in the increased water temperature observed in Jordan Creek relative to other mountain streams of comparable size. For example, Jordan Creek was 4.5 C warmer than the larger U. Yankee Fork Creek. In addition, tremendous growths of green algae (*Cladophora*) were present in Jordan Creek that were not seen in the other sites. Periphyton AFDM values also were higher in Jordan (and L. Yankee Fork) than in U. Yankee Fork.

The high AFDM value in WF Yankee Fork was a result of a substantial *Sphaerotilus* bloom that covered much of the stream bottom. This bacterium is indicative of organic enrichment from anthropogenic sources and suggests a potential pollution problem on the WF. Yankee Fork. Consequently, future comparisons among sites should concentrate on differences between U. Yankee Fork (as the reference condition) and Jordan and L. Yankee Fork Creeks. Further, additional examination should be conducted on WF. Yankee Creek to determine the cause of the *Sphaerotilus* bloom.

In this context, Jordan Creek had fewer taxa but greater density of macroinvertebrates than U. Yankee Fork. The greater density was a result of the predominance of chironomids in Jordan Creek relative to U. Yankee Fork. U. Yankee Fork also had a higher abundance of scrapers than Jordan Creek, suggesting the green algal bloom in Jordan Creek may constrain the feeding of these taxa. The large filterer, *Arctopsyche grandis*, also was quite abundant in Jordan and L. Yankee Fork but not in U. Yankee Fork implying a higher concentration of sestonic particles in Jordan and L. Yankee Fork. In summary, habitat conditions in Jordan Creek have resulted in a shift in benthic assemblage structure that differs from that found in U. Yankee Fork. However, most taxa found in U. Yankee Fork also were collected in reduced numbers in Jordan Creek, suggesting high potential recovery once habitat conditions are improved.

Acknowledgments

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